HISTORICAL OVERVIEW OF IOWA BRIDGES
Iowa Historic Bridges Recording Projects I and II
Iowa Department of Transportation
Ames
Story County
Iowa

HAER No. IA-88
HAER
IOWA
85-AMES, 7-

WRITTEN HISTORICAL AND DESCRIPTIVE DATA

HISTORIC AMERICAN ENGINEERING RECORD
National Park Service
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IOWA
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HAER No. IA-88

Location:	Iowa Department of Transportation, Ames, Story County, Iowa.
Date of Construction:	Various — see HAER documentation for individual structures.
Designer/Builder:	Various — see HAER documentation for individual structures.
Present Use/Owner:	Various — see HAER documentation for individual structures.
Historian:	James C. Hippen, September 1998.
Project Information:	This historical overview of bridges in Iowa was prepared as part of Iowa Historic Bridges Recording Projects I and II, conducted during the summers of 1995 and 1996 by the Historic American Engineering Record (HAER). The purpose of the overview was to provide a unified historical context for the bridges involved in the recording projects. See HAER Nos. IA-15 (addendum), IA-43 through IA-62, and IA-64 through IA-75 for bridges recorded as part of Iowa Historic Bridges Recording Project - I. See HAER Nos. IA-10 (addendum) and IA-76 through IA-87 for bridges recorded as part of Iowa Historic Bridges Recording Project - II. See also HAER No. IA-4 for the Marsh Rainbow Arch Bridge in Newton (1927), HAER No. IA-19 for the Freeport Bridge near Decorah (1878), and HAER No. IA-29 for the Rock Valley Bridge near Marshalltown (1918); all mentioned in this report.

Introduction

The purpose of this brief essay is to provide a background for the interpretation of the bridges recorded as part of the Iowa Historic Bridges Recording Project - I and II. Attention is given to the circumstances — geographic, economic, political — which controlled the bridging of Iowa. The persons and ideas involved in the building of the state's spans are given a tentative evaluation. Most importantly, a chronology of bridge development and usage in Iowa is suggested for the years from settlement to the interstate highway era.

Why Iowa?

The state of Iowa, as a unit for the study of a technological process that responded essentially to the natural shape of the land, may seem somewhat arbitrary. However, as soon as one asks *why* bridges were built in a certain place, designed in a certain way, and called upon to perform a certain task, the historical entity known as a state becomes a key to understanding the engineering and social history of bridges.

As Joseph Frazier Wall has pointed out, Iowa is, geographically, a sort of microcosm of the United States.[1] All the state lacks, from the standpoint of civil engineering, are mountains and seacoasts. This overview is concerned with bridges, not tunnels, so the mountains are not a crucial omission. Except for bascule and other moveable bridges found in coastal and large lake environments, Iowa has or had examples of all the major bridge types used by engineers from the 1840s on. Thus the state is a good sample of American bridge-building practice.

Iowa's bridges have been influenced by both natural and man-made factors. The natural features that shaped the state were more or less arbitrarily selected when boundaries were laid out on the mass of land acquired by the Louisiana Purchase. Once included within the state, the land and its topographical features formed the first elements of control. The terrain is relatively level, varying in elevation from 477 feet in the southeast at Keokuk in Lee County to 1,670 feet in the northwest in Osceola County. In this modest range of about 1,200 feet there are numerous occasions for bridges, due to the many streams that run their course to the Mississippi and Missouri rivers. The largest of the state's rivers, the Des Moines, has carved a valley that requires in places a structure nearly 200 feet high. The eastern and western border rivers — the Mississippi and the Missouri — have by their depth and width always demanded major bridges.

In addition to topography, the Iowa climate has had considerable impact on bridges built within the state. Northern Iowa lies within "the world's most extreme climate," and most of the state has an annual range of monthly mean temperature of fifty-five degrees Fahrenheit or more.[2] This has put unusual stresses on bridges in several ways. Piers, abutments, and the lower chords

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[1] Joseph Frazier Wall, *Iowa: A Bicentennial History* (New York: Norton, 1978), p. 45.

[2] John R. Borchert, *America's Northern Heartland* (Minneapolis: University of Minnesota Press, 1987), pp. 7-8.

of spans are battered by ice each winter and all sorts of floating debris in times of high water (including liquefied petroleum gas tanks in recent years). The extremes of temperature, combined with abundant rainfall, assail the materials of concrete and wooden bridges. Snow adds to bridge load, but more importantly its removal brings forth aggressive snowplow drivers and showers of road salt.

The pattern imposed upon Iowa by human agency has always rivaled nature's hand in establishing the way bridges are placed and used. Two factors in particular have combined to make Iowa a land of many bridges. The rectangular survey system adopted by the Land Ordinance of 1785 established a grid of east-west and north-south lines.[3] These crossed the landscape without regard to topographic features. Obviously this system, if roads were built on the grid lines, would generate an immense amount of arbitrarily placed bridges. The second factor, which caused such a seemingly illogical placement of bridges, was the fact that Iowa land is of such high quality for farming. Iowa, in its 56,000 square miles, has one-fourth of all the Grade I (excellent) agricultural land in the United States. Seventy-three percent of the land in the state is rated "excellent"; only four percent is "poor" or "incapable of tillage."[4] Thus Iowa as it was settled became covered with farms, prosperous farms, virtually everywhere. Farms were surveyed on the grid, and the least disruptive location for roads was on the grid lines. Wagon roads and the later automobile highway system were molded to fit section, township, and range. Railroads, of course, followed the dictates of the surveyors' instruments. Furthermore, the rail system, vast as it was, had a mileage of only one tenth that of the road network, and thus required only a fraction of the number of bridges needed on the public roads. Nature, in any event, provided plenty of occasions for the railroads to build bridges, especially since the tracks favored the east-west pattern of settlement that swept across the plains.

Iowa's counties — the most powerful unit of local government in the nineteenth century — were also laid out on a grid system, spreading in nine fairly regular east-west rows, averaging eleven counties in length. Of the ninety-nine counties, in the year 1900, only three had less than 10,000 people and only seven had more than 40,000.[5] The population was evenly distributed, and so was the political power. Bridges were a local responsibility, and the counties had the wealth and the desire to build them. Thus the survey system, the richness of the land, and the political position of landowners combined to produce a network of thousands of bridges. The railroads imposed their own bridge system, completed along with the track. Actually, the railroads built two systems, one to serve local and statewide needs, and the second a

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[3] The impact of this survey system is discussed in Hildegard Binder Johnson, *Order Upon the Land: The U.S. Rectangular Land Survey and the Upper Mississippi Country* (New York: Oxford University Press, 1976).

[4] H. L. Nelson, *A Geography of Iowa* (Lincoln: University of Nebraska Press, 1967), p. 35.

[5] *Iowa Official Register for . . . 1909-1910* (Des Moines: 1909), pp. 810-813.

strengthening and intensification of the first along certain routes to provide Iowa's share of the transcontinental service. Bridges served the same purpose on any railroad line, but the main lines were always at the forefront of design and maintenance while the branch lines had to make do with less. Finally the automobile, quickly becoming indispensable in the twentieth century, began to shape the road system and therefore its bridges. Bridges, although meaningful in their own right as engineering structures and architecture, are historically part of the transportation infrastructure. The chronological development of transportation in Iowa is therefore the key to Iowa bridge history.

Iowa Bridge Chronology

Iowa bridge chronology falls into three divisions, with some overlap: phase one, settlement, from the 1830s to circa 1870; phase two, railroads and wagon roads, from the 1860s to circa 1915; and phase three, the automobile age, from circa 1915 to the present.

The first phase of Iowa history, from the standpoint of a developing infrastructure, is the era of settlement. A significant influx of settlers began in the 1830s. The census of 1840 recorded population in only eighteen counties. By 1850, four years after statehood, half of Iowa's counties showed population. By 1860 all but two of the ninety-nine counties had some settlers. In 1870 only six counties had less than one thousand people, while five had more than thirty thousand each.[6] Civil government was organized in all counties by 1871.[7]

"Settlement" was a wave of activity that passed over the land rapidly, in general from southeast to northwest. There was no hard line of demarcation, and no exact date can be assigned when any particular area was "settled". But the figures cited above indicate the outer limits. From the standpoint of bridge construction, settlement was served if the immigrants could reach their land with dry feet. Fords and ferries were used where conditions allowed or demanded. Bridges, the best plan for middle-sized streams where neither ford nor ferry was feasible, were built of wood. These were either pile, trestle, beam, or simple truss structures. They have not survived, though occasionally what might be called functional replicas can be found. A few wooden pile road bridges exist in such a condition that they approximate those of a century ago. Fords are still used on some county roads, sometimes reinforced with concrete bottoms or fitted with culverts to make the crossing dry at low water.[8] Ferries are sometimes established on an ad hoc basis when a major river crossing is closed for repairs.[9] The primitive

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[6] *Census of Iowa for 1880 . . . With Other Historical and Statistical Data* (Des Moines: 1883), pp. 196-199.

[7] *Iowa Official Register for . . . 1909-1910,* p. 687.

[8] Fords are closed by high water and are also rendered unusable by ice jams in the winter.

[9] The temporary closure of the new Marquette bridge in the 1980s, due to structural deficiencies, is a case in point. Despite the institution of ferry service, the local economy on both

nature of the bridge infrastructure of this early phase must be left largely to the imagination, aided by these rare modern instances of what was once the norm.

Little quantitative information has been published on the wagon bridges of the settlement era. The records of individual counties and townships offer the best possibility, but this will involve an immense amount of research. In many instances, it is likely that systematic bridge records did not begin until after the settlement period. Winneshiek County, for example, started its "Bridge Expense Journal" in 1872. By then the county was certainly settled, with a population of 23,000. The journal is a chronicle of the installation of the new iron bridges, but it also reveals what preceded them. For example, the Freeport Bridge (HAER No. IA-19), an iron bridge installed new in 1878, replaced a bridge that required frequent repairs to its "bents," "trussels," and "tressels."[10]

Early maps show that river crossings were avoided if possible. Military roads in territorial days ran when they could either along the ridge between the watersheds of streams or parallel to the stream in its valley.[11] The road patterns in the earliest settled parts of the state, which were mainly in the valleys of the larger rivers, avoided unnecessary crossings and their appurtenant bridges.[12] The settlement phase of bridge building can be summed up as an era of wooden structures built only when absolutely necessary.

The second period of Iowa bridge building utilized the full resources of a prospering agricultural state and a national industrial economy. The modern theory and practice of bridge engineering developed as Iowa did. Squire Whipple published his *Work on Bridge Building* in 1847 and Herman Haupt his *General Theory of Bridge Construction* in 1851; Iowa became a state in 1846. The American iron industry produced abundant materials, and engineers and bridge manufacturing companies utilized iron and wood to produce ever more sophisticated designs.[13] The necessary market for vast numbers of bridges was provided by the expanding railroad system. Iowa's population and railroad mileage developed as shown in Table 1.

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sides of the Mississippi was adversely affected.

[10] Data compiled from *Winneshiek County Bridge Expense Journal, 1872-1892* (Winneshiek County Historical Society Archives, Luther College Library, Decorah, Iowa).

[11] W. Barrows, *A new Map of Iowa* (Cincinnati: 1845); A. J. Johnson, *Johnson's Iowa and Nebraska* [map] (New York: 1864); A. T. Andreas, *Illustrated Historical Atlas of the State of Iowa* (Chicago: 1875).

[12] "Iowa's Road Network" [map], in *Iowa Highway Needs, 1960-1980* (Washington: Automotive Safety Foundation, 1960), p. 20.

[13] The general chronology of American bridge engineering is best followed in Carl Condit, *American Building Art,* 2 vols. (New York: Oxford University Press, 1960 and 1961) and Eric DeLony, *Landmark American Bridges* (New York: American Society of Civil Engineers, 1993).

Table 1 Iowa Population and Rail Mileage, 1840-1920.

Year	Population	Rail Mileage
1840	43,116	—
1846	96,088	—
1850	192,214	—
1860	674,913	331
1865	756,209	847
1870	1,194,020	2,683
1875	1,350,544	3,823
1880	1,624,615	4,977
1885	1,753,980	7,478
1890	1,911,896	8,412
1895	2,058,069	8,486
1900	2,231,853	9,171
1905	2,210,050	9,826
1910	2,224,771	9,781
1915	2,358,066	10,002
1920	2,404,021	9,841

Sources: for population figures, *Iowa Official Register 1915-1916* and *Iowa Official Register 1927-1928;* for railroad mileage, Ray L. Bryant, *A Preliminary Guide to Iowa Railroads* (Iowa City: 1984).

The rail system had several interlocking purposes. Above all, in the nineteenth century, it was the state transportation network. The network served the existing population and economy, and extended settlement into new areas of the state. Railroad land bureaus were promoting the sale of farms and city lots as late as the 1890s. The other great function of Iowa railroads was to serve as a link in the transcontinental route, which meant essentially the connection from Chicago to the Union Pacific Railroad in Council Bluffs.

The other aspect of this second phase of bridge building was the demand for more permanent, less maintenance-intensive bridges for wagon roads. The increasing prosperity of the state made it possible for counties to build bridges on the grid of section lines, thus serving the agricultural population without disturbing their property lines. Wagon roads, it must be remembered, were for predominantly local traffic. They were seen as feeders for the rail system. Maintenance of roads was, outside of cities, the responsibility of townships or counties. Roads were graded dirt, involving little initial expense beyond surveying, sod busting, and grading.

Therefore, a high percentage of local road money could go into bridges. What was a fantastic luxury in the 1840s and 1850s became commonplace in the 1870s and 1880s.

Regarding the nature of the bridges which formed part of this transportation infrastructure, one can go beyond the approximations used in discussing the settlement period. The railroads combined financial resources and central planning to erect complete systems of bridges. They could, within their means, choose the form of bridge structure which best suited their requirements. But economy was required as well as structural adequacy. Consequently, the bridges of the early railroad infrastructure were mostly of wood. The amount of wood used in American railroad construction was enormous (not to mention the wood expended as locomotive fuel). Iowa, although not a heavily forested state, had easy access to timber. The forests of Wisconsin and Minnesota were felled and rafted down the Mississippi River. Railroads could transport their own construction materials efficiently and cheaply. Wooden bridges could be fabricated on site by construction crews, with a modest number of shop-produced iron parts.

For evidence, one can turn to the reports of the Iowa Board of Railroad Commissioners. In 1878 the first report included statistics on the existing railroad bridges in Iowa (see Table 2).

Table 2 Iowa Railroad Bridges, 1878.

Type	Number	Aggregate Length (ft)
Wooden	1,219	139,552
Iron	54	13,942
Stone	333	5,596
Wooden Trestle	5,386	527,904
Combination[a]	20	5,485

Source: Iowa State Board of Railroad Commissioners, *First Annual Report. . . for the Year Ending June 30, 1878. . . .* (Des Moines: Iowa State Board of Railroad Commissioners, 1878).

[a]The definition of a "combination" bridge as one with wooden compression members and iron tension members was widely accepted by the last decades of the nineteenth century. Edwin Thacher, in "Bridge and Concrete Steel Construction," *Cornell Civil Engineer* (1902): 1, stated this definition in reference to a career in bridge design that began around 1870. Exactly when the usage was established is not certain, as at least one earlier writer used "combination" to indicate a bridge combining cast and wrought iron; see George L. Vose, *Handbook of Railroad Construction* (Boston: Munroe, 1857), p. 195.

Average lengths give some indication of the types of bridges in use. The wooden bridges averaged 114 feet in length; even if many were simple beams of around twenty feet, the rest would have been trusses, many over 114 feet long. The iron and combination bridges averaged 258 and 274 feet; clearly most were trusses. The stone ones averaged only sixteen feet; most were little more than culverts.

Also reported in 1878 were the bridges built during the preceding fiscal year, 1877-1878. The figures are difficult to quantify because they were not uniform. (The Illinois Central, for example, reported "a number . . . part of Howe truss pattern, the rest, pile trestles.") Still, though all bridges in the state were not reported, some 248 railroad bridges were recorded as built in fiscal year 1877-1878. Of these, 173 were pile and trestle bridges. That leaves seventy-five. Classified according to material, these seventy-five break down into seven of stone, ten of iron, seven combination, and fifty-one of wood.

The predominant non-pile-and-trestle bridges were wood, and the most-used type was the Howe truss. These Howe trusses ranged from 66 to 260 feet in length. Other wooden types mentioned are "wooden girder," "A truss," "straining beam truss," "brace bridge," "arch," and "queen truss." The combination bridges were "Fink," "Howe," "double intersection," and "Pratt." The iron bridges were five girders from thirty-five to forty-two feet in length for the Chicago, Burlington and Quincy, and five 110-foot Pratt spans for the Keokuk and Des Moines.

When the type of wood was specified, it was usually "pine timber." The Dubuque and Dakota reported in 1881 that its pile bridges, with ten- and twenty-foot spans, had: "pine, elm, and oak piles; pine stringers and caps; oak and pine ties."[14] None of this timber was treated to prevent decay, so replacement came after a few years. In 1882, for instance, the Chicago, Rock Island and Pacific used 1,372,821 board feet of timber to renew wooden bridges, and the Chicago, Burlington and Quincy used 2,390,114 board feet.[15] Obviously the bridge crews were busy. The Chicago, Milwaukee and Saint Paul, for example, reported in 1884 that the average number of years that trestle and pile bridges lasted was six to eight, and that wood truss bridges lasted six to eight years "not roofed in," twelve to sixteen "when roofed."[16] Other lines reported similar figures. The apparent advantage in longevity of covered bridges for railroad use was offset by the added cost, difficulty in replacing timbers, and increased danger of fire. The railroad companies, as long as they stuck to wood construction, were rebuilding all of their bridges every decade.

The advantages of iron bridges were apparent, but the fact that Iowa railroads were trying to develop revenues, and the seemingly inexhaustible supply of pine floating down the Mississippi River, tended to restrict the use of iron to bridges of main-line importance. The White Water Creek Bridge in Dubuque County (HAER No. IA-51) is an example. Completed in 1872 as an adjunct to the Illinois Central crossing of the Mississippi at Dubuque, its design represented a use of materials (wrought iron with cast iron joint fittings) that would be superseded in a few years. Nonetheless, it was typical in size and truss system of iron railroad bridges in Iowa. It took decades, however, before wooden bridges were completely replaced by iron. As late as 1896, when there were 281 iron or steel truss bridges over 100 feet in length,

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[14] Iowa State Board of Railroad Commissioners, *Report . . . 1881,* p. 329.

[15] Ibid., *Report . . . 1882,* pp. 238, 138.

[16] Ibid., *Report . . . 1884,* p. 232.

there were still 153 wooden truss bridges over 100 feet on Iowa's rail lines.[17] As might be expected, wooden bridges were not infrequently kept in service long beyond the ten years that was their theoretical life. One example was the Stockwell Bridge on the Chicago Great Western at Waverly, which was a combination truss. Nearly forty years old in 1914, it was being converted piece-by-piece to a steel bridge when it collapsed under a train, killing two people and injuring many.[18] It is only fair to note that this disaster was on a branch line, which, while small consolation to the victims, was where wooden trusses would be found after 1900.

The county roads were the other great field for bridge building in the era from the 1840s to the 1890s and on into the twentieth century. Wagon bridges varied in material and design, but all shared the characteristics of being designed for a modest load, a usual width of sixteen or eighteen feet, and a length rarely exceeding 200 feet. Even bridges across large rivers such as the Des Moines or the Cedar were made up of a series of spans, each span resembling the single spans found on many country roads. Another characteristic of these wagon bridges was their ease of assembly. Iron and combination bridges were put together from relatively small parts, connected by pins or other joints that minimized field rivets. Thus they could be easily transported by horse and wagon from the railroad and erected by a few workers with hand-cranked derricks. Small concrete bridges, as they became popular in the first decade of the twentieth century, were even easier to build with untrained labor.

The bridges documented as part of the Iowa Historic Bridges Recording Project - I during the summer of 1995 are a representative grouping. They are predominantly from this era of wagon bridges. Twenty-three bridges fit into this category, out of a total of thirty-four surveyed. Included are six tied-arch or bowstring bridges and twelve trusses (ten through, one deck, and one pony) which represent the widespread use of both types in the 1870s and early 1880s, with trusses of straight chord elements winning out by the 1890s. Also documented by HAER was one stone arch, the Elkader Bridge (HAER No. IA-47), a type used less frequently for wagon than for railroad bridges. That famous specimen of American culture, the Madison County covered bridge (HAER No. IA-64), shows an example of wooden bridges trying to compete with iron in the 1870s. Three concrete bridges (ranging from 1893 to 1914) are examples of new materials applied to the old requirements of wagon bridges.

The evolution to a new phase in Iowa bridge history is the next major issue to be considered. However, before this point is discussed, it is necessary to note the divergence of railroad and wagon bridge development. Railroad bridges required improved designs not because Iowa was building many new routes (the systems were essentially complete in the 1890s), but because the weight of locomotives and cars kept increasing. Comparing, where

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[17] Ibid., *Report . . . 1896.*

[18] Newspaper clippings, October 1914 (Waverly Public Library, Waverly, Iowa); postcard views (author's collection).

possible, the same type of engines from the 1870s to those of the early twentieth century shows the trend of development (see Table 3).

Table 3 Weight of Locomotives, Without Tender.

Type	1870s Weight (tons)	1906 Weight (tons)
American (4-4-0)	31	47
Ten-Wheel (4-6-0)	39	66
Consolidation (2-8-0)	48	81
Pacific (4-6-2)	—	113
Mikado (2-8-2)	—	119

Sources: for the 1870s, Matthias N. Forney, *Catechism of the Locomotive* (New York: 1881); for 1906, Mansfield Merriman, *American Civil Engineers' Pocket Book* (New York: Wiley, 1911), p. 206.

In a sense, the development of railroad bridges merely continued to the maximum in the direction dictated by gauge and clearance, which did not change. After the tubular space above the rails was packed with as much locomotive or freight train as possible, the design of railroad bridges had reached its natural limit. Thus the Boone Viaduct of the Chicago and North Western Railroad (HAER No. IA-44), built in 1901, still carries main-line traffic.

Wagon bridges had less strenuous requirements; more experimentation was possible. One example is the Middle Creek Bridge (HAER No. IA-66), a small truss built of iron pipe with cast iron joints, designed by an Iowa company in the 1890s. Although some of these have lasted a hundred years, the use of cast iron was a throwback to the designs of the 1860s. However, as wagon bridges became both larger and more common, they began to assume proportions that would allow them to become highway bridges. In 1887, at Dubuque, the first wagon bridge crossed the Mississippi into Iowa. Previously the only road crossings of that river were incorporated in railroad bridges. With regard to smaller structures, around 1900 riveted trusses and concrete added stability to wagon bridges which soon would be pressed into service as automobile bridges.

And that — the automobile — is the defining element for the third phase of Iowa bridge history. Statistics of registration (see Table 4) show the growth of a new transportation system which quickly moved beyond its role as a railroad feeder to an alternative to the railroads.

Table 4 Iowa Motor Vehicle Registrations, 1905-1980.

Year	Number of Vehicles
1905	799
1910	10,422
1915	147,078
1920	437,378
1925	659,202
1926	718,013
1927	782,634
1980	2,329,000

Sources: William H. Thompson, *Transportation in Iowa: A Historical Summary* (Ames: Iowa Department of Transportation, 1989), p. 141; *Statistical Abstract of the U.S. 1991*, p. 608.

Coincidental with the rise of the automobile was the move toward centralization of control over bridges. This was a national movement, in reaction to a host of abuses in the letting of bridge contracts, deficiencies in design and maintenance, and in line with the general trend of the Progressive Era toward administrative efficiency and professionalism. In 1904 Iowa established a Highway Commission, which was an advisory committee made up of faculty (engineering and agriculture) of Iowa State College. Although lacking political authority, they managed to produce recommended standard designs for reinforced concrete culverts, and designed bridges for important sites, such as the Kilbourn Bridge (HAER No. IA-85) spanning the Des Moines River. This is a six-span Pratt truss designed by T. H. MacDonald and J. E. Kirkham, both of whom were eventually to achieve national importance in the fields of bridge and highway design.[19] In 1913 the highway commission was reorganized as a separate agency, although retaining connections to the state engineering school at Ames. With power to approve all major bridge contracts and supervise the newly created county engineers, the commission acted to improve the quality and honesty of bridge work in Iowa. Standard plans were issued for smaller bridges, including trusses up to 150-foot span. Larger bridges were custom designed. This led to widespread changes in bridge construction in the state, such as the abandonment of pin connections for smaller trusses and the phasing out of several exotic types of patented

[19] "The Standard Reinforced Concrete Culvert Construction of the Iowa State Highway Commission," *Engineering-Contracting* 31 (3 March 1909): 176-177. Photos of Kilbourn bridge by author, 1981 and 1986. FRASERdesign, *Iowa Historic Bridge Inventory* (Ames: Iowa Department of Transportation, 1992-1993).

concrete bridges.[20] Active along with MacDonald and Kirkham was Conde B. McCullough as designing engineer, another person to achieve a national reputation in bridge design. The existence of the commission helped the state deal with the explosion in highway use caused by the automobile in the second and third decades of the twentieth century.

One feature of the motoring revolution was the designation of systems of highways. This began first with private promotional efforts, such as the Lincoln Highway Association in 1913, part of a widespread movement to produce automobile guides and to designate routes. The culmination in Iowa was the establishment of a state primary road system in 1919, followed by numbering of a federal network in 1926 and 1927. The impact on bridges was similar to that of railroads in the nineteenth century: once a specific route was established, its quality could be evaluated and brought up to a certain standard.

The bridges on early motor routes were the result of efforts by the various counties and cities along that route. Standards varied a good deal. The "Iowa Official Trans-Continental Route" was the unofficial precursor to the Lincoln Highway and U.S. Route 30. In 1912 the road from Clinton to Council Bluffs, largely unpaved, had fifty-two steel and forty-six concrete bridges. However, it also had 135 wooden bridges and two fords.[21] Local business boosters and an enthusiastic motoring public, willing to pay road use taxes and accept federal aid, were balanced against fiscal conservatives who wanted lower taxes and less centralized control. By the 1920s, however, the increase of traffic and the obvious benefits to local business and agriculture convinced the majority to move ahead with highway and bridge construction on a large scale.

The Iowa Historic Bridges Recording Project - I during the summer of 1995 documented important examples from the first decades of the third, automobile, phase of Iowa bridge history. The Keigley Branch Bridge (HAER No. IA-74) is a concrete arch design by the highway commission to demonstrate the right way to build such a bridge, a sort of riposte to Daniel B. Luten's patented design (HAER No. IA-53). The Court Avenue Bridge (HAER No. IA-70) is an example of the Beaux Arts and City Beautiful influence in architecture and planning. The Lincoln Highway Bridge in Tama (HAER No. IA-75) is a standard small concrete bridge

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[20] The history of the Highway Commission is summarized in George S. May, "The Good Roads Movement in Iowa," *Palimpsest* 46 (February 1965): 81-95, and Thompson, *Transportation in Iowa,* pp. 76ff. The reports of the commission are very useful, especially *First Annual Report . . . April 9, 1913 to . . . December 1, 1914* (Ames: Iowa State Highway Commission, 1915). Many of the early standard plans are available in Iowa State Highway Commission, *Bridge Standards . . . Obsolete,* 2 vols. (Ames: Iowa State Highway Commission, 1972).

[21] Melchior Huebinger, *Huebinger's Map and Guide for Iowa Official Transcontinental Route* (Des Moines: Iowa Publishing Company, 1912).

embellished with a balustrade spelling out "LINCOLN HIGHWAY". The importance of the motor car was thus literally set in concrete.

The financial possibilities of automobiles and toll bridges were not lost on entrepreneurs in the 1920s. The Plattsmouth Bridge (HAER No. IA-67) is an example of the private toll bridge enthusiasm that flourished before the Depression, and it is the oldest remaining highway bridge from Iowa over the Missouri River. The Black Hawk Bridge (HAER No. IA-43), a beautiful cantilever, and the Alden bridge (HAER No. IA-56) were both planned to meet the needs of the automobile era. In 1940, the Centennial Bridge (HAER No. IA-73), designed by Ned Ashton, forecast the shape of many large bridges of a later era. And the stringencies of World War II, when most improvements to the infrastructure had to wait, are evident in the bowstring bridges of Crawford County (see HAER No. IA-48).

Taking up the other thread of bridge engineering, the railroads, one finds a transportation technology entering a long era of retrenchment. The third phase of Iowa's transportation and bridge history, based on the automobile, has little special meaning for the railroads. Their infrastructure is a continuation of that which was in place in 1915, on a shrinking scale. Improvements in main-line tracks and bridges continued, but in Iowa alone thousands of miles of branch lines and even some of the mains have since been abandoned. The bridge of choice has become the plate girder. These are used to replace trusses wherever possible, primarily because of lower maintenance costs. As always, the railroads are economical in their use of bridges, using second-hand plate girders from abandoned lines in many cases.[22] In the prosperous days of the 1920s, even though mileage was starting to slip and passenger business was losing to automobiles and buses, the railroads built great bridges when the need arose. The Atchison, Topeka and Santa Fe Railroad bridge at Fort Madison (HAER No. IA-62) set an example for heavy swing bridges.[23]

While most highway bridges of the 1920s and 1930s followed in the traditional design modes — simply supported trusses and beams — there were an increasing number of experiments with new designs. The most important of these, with reference to their long-term use up to the present, were those involved in the development of continuous bridges.

The continuous beam, girder, or truss bridge has the advantage over simply supported structures in savings of material and greater stiffness.[24] This was demonstrated on a grand scale

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[22] In the last twenty years the author has witnessed several such instances on the Milwaukee Road (then Soo Line/CPRail, now I&M Rail Link) in northeast Iowa.

[23] See, for example, Thomas Clark Shedd, *Structural Design in Steel* (New York: Wiley, 1934), pp. 41, 45, 46, 57, 58, 163, 264.

[24] The principle of continuity is clearly explained in chapter 3 of Harry Parker, *Simplified Design of Reinforced Concrete* (New York: Wiley, 1943), and later editions of the same work.

by Robert Stephenson's Britannia Bridge, completed in 1850.[25] American engineers, however, were slow to adopt the idea of structural continuity in a bridge, considering it impractical both because of its vulnerability to the effects of pier settlement and the difficulty of calculating the stresses involved.[26] A few examples were built in North America, and the theory found its way into textbooks. The attitude of the great majority of engineers, however, was summed up and fortified by J. A. L. Waddell, the *pontifex maximus* of the profession, who concluded that "few American engineers will countenance the building of continuous girder bridges."[27] In 1917, the next year, Gustav Lindenthal completed the great Sciotoville, Ohio, continuous truss, and engineers began a slow realization of the practical possibilities in the continuous approach.[28]

Now this overview can begin to concentrate on Iowa. There, as in the profession generally, engineers edged up to a previously condemned idea with care. In trusses and in girders, the nearest thing to a continuous structure is a cantilever. For major bridges such as crossings of the Mississippi and Missouri rivers, cantilever trusses had been used for decades. Iowa's first large continuous truss was the Nebraska City bridge spanning the Missouri River, built in 1929.[29] Others were built in the 1930s to span the Mississippi, the Missouri, and the Des Moines rivers.

Of wider importance throughout the state was the gradual acceptance of continuous structures for moderately large crossings. The first, so far as is known, was designed by the highway commission to replace a Luten patented arch that collapsed in Ames. Built to carry the Lincoln Highway over Squaw Creek, the bridge was a three-span steel through plate girder, and it was continuous. The inflammatory word "continuous" was not used, however, in describing the bridge. Captions to published photographs merely call attention to the beauty of the "continuous curve" of the camber of the bridge, "instead of a series of lines breaking at the pier points."[30] Also noted is the fact that the three girders are "permanently connected to each other end to end," thus saving in the number of supports needed on the top of the piers.[31] If this seems

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[25] Charles Singer, et al., *A History of Technology,* vol. 5, *The Late Nineteenth Century* (Oxford: Clarendon Press, 1958), pp. 504-505.

[26] George A. Hool and W. S. Kinne, *Movable and Long-Span Steel Bridges,* 2nd ed. (New York: McGraw-Hill, 1943), pp. 199-201.

[27] J. A. L. Waddell, *Bridge Engineering,* 1st ed. (New York: Wiley, 1916), p. 482.

[28] Carl Condit, *American Building Art: The Twentieth Century* (New York: Oxford University Press, 1961), pp. 92-100.

[29] Sverdrup and Parcel, *Engineering Projects* (Saint Louis: Sverdrup and Parcel, 1946).

[30] Iowa State Highway Commission, *Service Bulletin* 9 (March-April 1921): 3.

[31] Ibid., p. 5.

to press a bit far the issue of disguising the new, one may also note that when the state highway system was established two years earlier, "so great was the opposition to the word 'state' and a state-controlled road system, that legislators, fearing for their political futures, named it the 'Primary Road System'."[32]

The cantilever design was also used first with regard to concrete structures. As early as 1905, a concrete cantilevered girder was built for the street railway in Marion.[33] The highway commission experimented with reinforced concrete cantilever girders, beginning with one at Woodbine (also on the Lincoln Highway) in 1917. Others followed, noted in the bridge design section of the commission's Annual Reports.[34] In 1926 the commission reported the design of a "monolithic concrete girder" that "makes use of the cantilever principle."[35] This was the Winnebago River Bridge (HAER No. IA-78) just north of Mason City.

But things began to change more rapidly. Other states were also introducing the continuous bridge.[36] By 1929 an editorial in *Engineering News-Record* could proclaim that "structural views have made distinct progress since the days when continuous bridges were considered bad practice."[37] Iowa began to regularly construct continuous bridges, usually of the steel plate girder variety.[38] Those built in the 1930s are remarkable examples of innovative design in response to the demands of the age of automobiles and highways.

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[32] Thompson, *Transportation in Iowa,* p. 73.

[33] This may have been the first such bridge in the nation. Carl Condit, *American Building* (Chicago: University of Chicago Press, 1968), p. 257.

[34] Those listed in FRASERdesign, *Iowa Historic Bridge Inventory,* are Herrold (1921, No. POLK13), Goldfield (1921-1922, No. WRIG27), Okoboji (1929, No. DICK01), and Spirit Lake (1939, No. DICK02).

[35] Iowa State Highway Commission, *Annual Report for 1926* (Ames: Iowa State Highway Commission, 1927), p. 15.

[36] Oregon State Highway Commission, *Eighth Biennial Report . . . 1926 . . . 1928* (Salem: Oregon State Highway Commission: 1929), p. 71.

[37] [Editorial], *Engineering News-Record* (17 January 1929): 89.

[38] The conclusion that few concrete continuous bridges were built is tentative. The *Iowa Historic Bridge Inventory* rarely identifies continuous structures, so it is of little value in checking among the surveyed items for this structural type. From an economic point of view, continuous concrete girders, due to cost of form work, would usually be more expensive and thus less common. The concrete bridge really came into its own with the introduction of prestressed beams after World War II.

The Iowa Historic Bridges Recording Project - II during the summer of 1996 continued within the chronological limits established in the previous year: from the 1870s to the Second World War. Some bridges were additions to the list of iron wagon bridges of the late nineteenth century. One, the Red Bridge (HAER No. IA-76) in the northeastern part of the state, although assembled in its present state in 1920, represents perhaps the earliest technology of any bridge known in the state; it is a combination bridge, a Pratt truss with wood for compression members and iron for tension members. Two concrete arches (HAER Nos. IA-77 and IA-79), while not avant garde, are superb examples of open- and filled-spandrel concrete arches. But half of the bridges recorded in 1996 are representatives of the varied experimentation that led to the perfection of the continuous bridge. They range from a concrete cantilever of 1926 (HAER No. IA-78) to a group of increasingly impressive beam and truss continuous structures of the 1930s (HAER Nos. IA-80, IA-81, IA-84, IA-86, and IA-87).

The Iowa bridge chronology developed above can be recapitulated as follows:

Phase I, settlement: 1830s to circa 1870.

Phase II, railroads and wagon roads: 1860s to circa 1915.

Phase III, the automobile age: circa 1915 to the present.

Thousands of bridges were built in response to this evolving transportation infrastructure. It remains to be seen where these structures came from; who built them?

Who Built the Bridges?

It is best to begin this section by dealing with the issue, seemingly not very complicated, of what it means to "build" a bridge. The agencies involved vary with the type of structure. Wooden bridges can be fabricated on site from standard timbers and iron stock obtained locally. A few good carpenters and a blacksmith, with assistants, can put up a Howe truss. Therefore anyone with an experienced bridge crew can build wooden bridges, if they have a design to follow. In the nineteenth century, railroads could either use their own crews or contract the work to bridge companies. Even large companies such as the Keystone Bridge Company built numerous wooden bridges.[39]

Iron and steel bridges, on the other hand, required a lot more expertise to build. The whole point of an iron bridge, especially a truss, was to use material economically. The first step, consequently, was to design the bridge according to engineering principles which would insure adequate load-bearing capacity for the least cost. The second step, although it did not necessarily have to be directly related to the bridge of step one, was to produce parts, i.e., I-beams and channels, eye-bars, pins, and other parts required to assemble a bridge. These would normally be made in the rolling mills and foundries of steel companies or iron works. The third

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[39] Keystone Bridge Company, *Descriptive Catalogue of Wrought-Iron Bridges* (Pittsburgh: Keystone Bridge Company, 1875), pp. 39-42.

step was to fabricate the bridge, that is, to take the I-beams and other rolled sections, cut them to size, punch and rivet them together into chord and web members, make joint assemblies — in short, to put together all the parts of a specific bridge ready for assembly on site. Usually this was done in the shop of a bridge company, separate from (although perhaps owned by) a steel or iron works. The fourth step was to erect the bridge on site. This could be done by an independent contractor, by a contractor acting as an agent for the bridge company, by the bridge company itself, or by the railroad or agency buying the bridge.

Concrete bridges were more analogous to wooden bridges in their mode of construction. The materials for the concrete, along with steel reinforcing and wooden timbers and planking for form work, could be delivered to the site without advance fabrication. At the site, a competent general contractor could build the bridge, providing adequate designs were furnished. Small rural stone arch bridges could be built in a similar fashion by most masons, but a large bridge (like the Elkader stone arch bridge, HAER No. IA-47) would require preliminary stone cutting and dressing at the quarry, work analogous to metal fabrication in a bridge shop.

Dozens of companies were involved in selling wagon bridges to Iowa counties in the decades from 1870 to 1910. Their particular styles can be recognized in surviving bridges, and their names appear in records.[40] They represent companies from the Midwest to the east coast. Many of the prominent suppliers formed their companies in the late 1860s or early 1870s; they were ready to take part in the boom years of bridge building.[41]

Perhaps the best way to appreciate the role of the companies is to look at a specific example. In Winneshiek County in northeast Iowa, the advent of iron bridges occurred in April 1873, when two of the county supervisors visited an iron bridge in a neighboring county. As a result, they recommended that "all larger bridges should henceforth be built of iron."[42] That summer four iron bridges were built by the Wrought Iron Bridge Company of Canton, Ohio. Through the 1870s the same company continued to build bridges for the county, completing twenty-two by 1880. Three other companies also built bridges in Winneshiek County during the 1870s: the Corrugated Iron Company of Chicago (seven), the King Iron Bridge company of Cleveland, Ohio (one), and the Moseley Iron Bridge Company of New York City (six). During

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[40] Scores of bridge companies and thousands of references to county records are mentioned in FRASERdesign, *Iowa Historic Bridge Inventory.* However, this author has not seen any statistical analysis based on the various mentions of bridge companies. In any event, the survey covered only existing highway bridges.

[41] Victor C. Darnell, *A Directory of American Bridge Building Companies, 1840-1900,* Occasional Publication No. 4 (Washington: Society for Industrial Archeology, 1984).

[42] Decorah *Republican,* 18 April 1873.

the 1880s, bridge work was taken over by Iowa firms. A local contractor built the smaller spans while D. H. Young of Manchester, Iowa, built the larger ones.[43]

This one example confirms what seems evident to a researcher of existing Iowa bridges: companies had certain counties as their territories. The engineering press is full of stories of crookedness and incompetence in the building of wagon bridges. J. A. L. Waddell gave a succinct account of the flawed process of letting bridge contracts in his *General Specifications for Highway Bridges of Iron and Steel* (1889).[44] A brief look at both of these issues is appropriate.

The geographic division of the spoils of bridge contracts can be established by the publications of the bridge companies themselves. Comparing the catalogues of the Wrought Iron Bridge Company for 1874 (Canton, Ohio) and the King Iron Bridge Company for 1884 (Cleveland, Ohio), one finds listings in the first for bridges built in twelve Iowa counties, in the second for twenty-five. There are only four counties common to both lists.[45] Of course, each built bridges in other counties; this list is only a selection. It is interesting to note that the bridges chosen for emphasis do show which counties each company tended to dominate.[46] The ten-year difference between the two lists naturally introduces some inaccuracy, but what is nicely demonstrated is the type of bridges they were trying to sell. The Wrought Iron Bridge Company in 1874 lists only various types of arch (or bowstring) bridges, while King in 1884 notes high truss, low truss, tubular arch, beam arch, channel arch, and combination bridges. Clearly, the trend was toward other types than just iron "arches" (bowstrings), but companies were willing to sell older as well as newer types.

In addition to the domination of certain areas by one company or contractor, there were other ways to avoid the deleterious effects of competition. Especially practiced was pooling. This involved several companies making similar bids. The lowest, who would get the contract, had included a commission for each of the other companies.[47] This led to a proliferation of bridge companies. As Waddell put it,

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[43] *Winneshiek County Bridge Expense Journal, 1872-1892.*

[44] Reprinted in John Lyle Harrington, ed., *The Principal Professional Papers of Dr. J. A. L. Waddell, Civil Engineer* (New York: 1905), pp. 205-255.

[45] Wrought Iron Bridge Company, *Book of Designs of Wrought Iron Bridges* . . . (Canton: Wrought Iron Bridge Company, 1874); King Iron and Bridge Manufacturing Company, *Catalogue* (Cleveland: King Iron and Bridge Manufacturing Company, 1884).

[46] Based on bridges seen or documented by the author. A detailed study of the evidence, including analysis of the *Iowa Historic Bridge Inventory,* is beyond the scope of this report.

[47] J. A. L. Waddell, "General Specifications for Highway Bridges of Iron and Steel," 1889, in *Principal Professional Papers,* p. 221ff; "The Letting of Highway Bridges" [editorial], *Engineering News* (19 January 1893): 61-62.

> Traveling men seeing what a profitable business attending bridge lettings had become, began to set up little bridge companies for themselves, thus increasing the number of competitors and filling the country with a crowd of so-called bridge builders, whose offices and shops often consist merely of desk room somewhere, and whose only desire in attending lettings is to extort blackmail.[48]

One might wonder how these persons so excoriated by Waddell managed to stay in the game. What happened when it was their turn to actually build a bridge? They could easily buy a well-designed bridge from a bridge shop and hire a contractor to erect it. An advertisement by the Cedar Rapids agent for the Indiana Bridge Company (circa 1906) proclaimed, "We Design and Build HIGHWAY AND R. R. BRIDGES . . . We furnish F. O. B. cars Bridge or Structural Steel complete and ready for erection, or we will erect ready for use. . . ."[49]

The picture of bridge companies soliciting the business for an emerging street and highway infrastructure becomes truly kaleidoscopic by the end of the nineteenth century. The Southwest Fifth Street Bridge in Des Moines (HAER No. IA-71) is a revealing example. Involved were nine competing bridge contractors, three of whom had, as late as 1893, been agents for the King Bridge Company of Cleveland, Ohio.[50] In 1896 they submitted bids for the new bridge in Des Moines over the Raccoon River. Eight of the bids were within a range of $1,600.00; the ninth was $5,800.00 lower. The result was a lawsuit against the low bidder that was finally decided in the Iowa Supreme Court; the low bidder won.[51] Here was the pool at work. Local newspapers did not hesitate to identify "the combine" of bridge men.[52] Before the court questions were asked: "whether or not there was any combination among these other bidders to pool among themselves on this bridge?"[53] Prudently, the Supreme Court sustained all objections to such a query. The "secret" of the bridge pool was protected, even though the rebel low bidder built the bridge. Had he played the game, all the others could have made over $700.00 each just for submitting a bid. The low bidder bought the bridge that he erected from his old employer, King Bridge Company of Cleveland.[54] This instance shows both the origin of

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[48] Waddell, "General Specifications," p. 223.

[49] Complimentary datebook for 1907, stamped "Indiana Bridge Co. . . . J. D. Palmer, State Agent, Cedar Rapids, Iowa."

[50] Des Moines *Saturday Review,* 11 February 1893.

[51] *C. Jenney* v. *City of Des Moines, et al.,* Supreme Court of Iowa, January Term 1897.

[52] Des Moines *Leader,* 11 August 1896.

[53] *C. Jenney* v. *City of Des Moines, et al.,* pp. 33-34.

[54] Des Moines *Leader,* 3 February 1898.

local bridge companies and the way the pool worked. Waddell and the other engineering critics were hardly exaggerating.

The bridge boom continued. In that monument to the emerging automobile age, Huebinger's *Automobile and Good Road Atlas of Iowa* (1912), one finds countless advertisements for hotels, automobile dealers, blacksmiths and garages, and bridge builders. Prominent among the latter are full-page displays by Marsh Engineering Company and N. M. Stark and Company, both part of the bridge pool in the Southwest Fifth Street Bridge case and both founded by former agents of King Bridge Company of Cleveland. One of these advertisements gives a succinct if rosy picture of how such companies worked.[55]

> N. M. Stark & Company is an organization which for twenty years has undertaken to design and construct bridges of every description, and, forseeing we were coming to permanent bridges, the last eight or ten years have been devoted almost exclusively to building bridges and culverts of reinforced concrete of different types. The work done covers the Middle West and principally in the State of Iowa, for counties, municipalities, and steam and electric railroads. In general, the organization consists of engineers and constructors skilled in design, equipment and field construction. In addition to the office engineering forces, there are necessary executive departments the heads of which are specialists in their divisions of engineering, bookkeeping, purchasing, freight and general service. In the field are superintendents, foremen, carpenters, blacksmiths, and common laborers.

What is conspicuously absent in the foregoing description is a bridge shop, a place where steel bridges are fabricated in preparation for erection in the field. Such a manufacturing facility is, of course, unnecessary for concrete bridges. And, as was noted previously, Stark or any other bridge contractor could purchase iron or steel bridges and build them under their own name.[56]

Iowa, in fact, had very few bridge shops. In 1917, only five firms manufactured bridges in the state (Table 5).

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[55] Melchior Huebinger, *Automobile and Good Road Atlas of Iowa* (Des Moines: Iowa Publishing Company, 1912), p. 94R.

[56] N. M. Stark did build iron and steel trusses; in Fayette County for example.

Table 5 Iowa Bridge Manufacturing Firms, 1917.

Manufacturing Firm	Location
Clinton Bridge Works	Clinton
Pittsburgh-Des Moines Steel Company	Des Moines
Seevers Manufacturing Company	Oskaloosa
Ottumwa Supply and Construction Company	Ottumwa
Red Oak Bridge and Iron Works	Red Oak

Source: Iowa State Bureau of Labor Statistics, *Directory of Manufacturing Establishments,* Bulletin No. 1 (Des Moines: Iowa State Bureau of Labor Statistics, 1919), pp. 168-177. The 1921 *Directory* (1919 data) lists the same five firms.

Because these shops had to purchase their rolled shapes and other basic components from mills out of state, they were not at any great advantage in competing for the Iowa trade with bridge shops in other areas of the country.

Besides urban and rural roads, the other great users of bridges in the state were the railroads. Data on railroad bridges is not easy to find, just as field access is often limited. One example of a main line, the Chicago, Burlington and Quincy, using 1925 reports, gives a clear idea of the origins and dates of the company's bridges at that time. The main line across Iowa was included in two divisions. The Ottumwa Division ran from Galesburg, Illinois, to the Mississippi River, crossed into Iowa at Burlington, and ran through Ottumwa to Creston. The Creston Division ran from that town through Red Oak to Council Bluffs. By type the bridges were mainly girder or beam structures. Of ninety-one bridges on the line, the only exceptions were four Pratt truss crossings. Although the majority of the bridges had been installed in the 1900-1904 modernization period, there were twelve spans dating from 1889 or earlier and thirteen from the period 1890-1899. Only nine spans dated from 1905-1925. The major manufacturers represented were American Bridge Company, forty-seven; Lassig, nineteen; and King, twelve. None of the bridges were built by Iowa companies.[57]

It must be stressed that the above is for a main line. Taking the other extreme, the branch line from Keokuk to Mount Pleasant had two crossings. The Skunk River was bridged by two through Howe truss spans, 149 feet each, built by Wells and French (of Chicago?) in 1893. Big Creek had a 143-foot Howe truss, built by Wells and French in 1889; it had a timber falsework pier in the center. All three of these timber spans were listed as "in poor condition."[58]

[57] Chicago, Burlington and Quincy Railroad Company, bridge inspection notes, fall 1925 (author's collection).

[58] Ibid.

Based on these examples, one may conclude that Iowa railroads got their bridges from large suppliers. Also, they maintained their spans to a standard which fit their own appreciation of needs. Highway bridges, on the other hand, were subject to public pressure through the governmental agencies that built and maintained them. The decision-making process was spread widely at the local level, and there were many local contractors and even some Iowa manufacturers who could compete successfully with out-of-state bridge builders. The question arises, was there any distinctive trend in bridge building linked to the Iowa market and its local suppliers?

Iowa's Contribution to Bridge Technology

In the early years of the twentieth century, Iowa was peculiarly suited to the development of an improved infrastructure designed to facilitate a uniformly high level of transportation efficiency over the whole state. Iowa's railroad system, fourth largest in the nation, needed only the local feeders provided by improved wagon roads, also suitable for automobile traffic. Numerous safe bridges were the key to progress. Iowa had the need, and Iowa had the means. Three facts from the state census of 1915 make the point: (1) "there is a more even distribution of population among all the counties of the state than in any other state of the union," (2) "Iowa ranks first in number of motor vehicles per population," (3) "Iowa ranks first in the United States in per capita wealth."[59] The state was destined to be a prime consumer of bridges. What did it contribute to the bridge building art?

There were two ways that bridge technology could be bettered as the Iowa infrastructure developed. One was to make sure that the application of technology on so vast a scale was brought up to the best possible standard of the times. The other way was to produce innovative designs which responded to Iowa needs and conditions.

The greatest success was in the area of applied theory and the reform of practice in the light of sound engineering principles. The lead was taken in a tentative way with the establishment of the first Iowa Highway Commission at Iowa State College in 1904. Along with concern for at least a minimum improvement (paving would come later) of the 100,000 miles of roads, there was the beginning of a movement toward reform of the abuses in bridge construction. Besides the financial evils of pooling and the occasional bridge so poorly built that it actually collapsed, there was the much more general issue of what is now called quality control. The commission in 1906 pointed out that the counties and townships had built "a heterogeneous combination of structures designed and constructed without system and in many cases without the thought of the traffic that they are compelled to carry."[60] As noted earlier, the

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[59] Iowa State Bureau of Labor Statistics, *Directory of Manufacturing Establishments,* pp. 19-20.

[60] Iowa State Highway Commission, *Second Annual Report . . . For the Year Ending July 1, 1906* (Ames: Iowa State Highway Commission, 1907), p. 25.

first commission produced standard designs that were optional; control over design standards came with the second commission established in 1913. This kind of engineering control, based on the work of the state engineering schools and following national trends, while it may have stifled some innovations by forcing bridge companies to adhere to highway commission standards, guarded against inadequate designs promoted for the sake of economy. For large projects the highway commission increasingly called on consulting engineers to refine and check designs (see, for example, HAER Nos. IA-79, IA-84, and IA-87).

But what about innovations in design, springing from the fertile minds of Iowa bridge designers, and producing solutions to Iowa-specific problems? The size of the United States by the early twentieth century, with a developed engineering profession across the country, meant that Iowa was only one among many fields for experimentation. There was little difference in the requirements for bridges from Michigan to Nebraska, from Minnesota to Missouri.

The most promising new area in bridge development was the application of concrete and reinforced concrete. A very early example occurred in Iowa in 1894 at Rock Rapids (HAER No. IA-63), but the engineering expertise was imported. Other patented reinforced concrete bridges were built in Iowa in the period from 1900 to 1920, but these were usually designed by out-of-state engineers, such as Daniel B. Luten of Indiana. Indeed, although the quality of the bridges built under Luten's patents varied, the effort he put into collecting royalties and suing for infringement was monumental. Eventually the Iowa Highway Commission became a co-defendant in a Luten suit, and won in 1918 when several of Luten's patents were judged invalid.[61] The patent situation was so annoying that one bridge engineer, Henry Grattan Tyrrell, observed in 1909 that "the principal reason for the existence of the many patented systems for concrete reinforcement is the patent royalty secured therefrom."[62]

The other defendant in the Iowa Luten case happened to be James B. Marsh, a Des Moines bridge engineer and contractor noted above in connection with the Southwest Fifth Street Bridge (HAER No. IA-71) in Des Moines. Even though Marsh and the highway commission eventually beat Luten, Marsh learned the lesson that it was a good idea to have patent protection if possible. And this he got for his own bridge design, a structure tailored to Iowa conditions. His "Rainbow Arch" was patented in 1912. (See, for examples, HAER Nos. IA-4, IA-29, and IA-46.) It was a reinforced concrete through arch, intended for small to medium spans. The design showed a masterly combination of the engineer's and the contractor's skills. It minimized materials and labor, and was able to compete in cost with steel trusses. For longer crossings multiple arches could be used as at Lake City (HAER No. IA-46). The viability of the design

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[61] Thomas H. MacDonald, "Bridge Patent Litigation in Iowa," *Iowa Engineer* 18 (January 1918): 117-127.

[62] H[enry] Grattan Tyrrell, *Concrete Bridges and Culverts* (Chicago and New York: Myron C. Clark, 1909), p. 117.

was demonstrated as late as 1930 with the Cotter Bridge in Arkansas which includes five 190-foot spans (HAER No. AR-15).[63]

Another bridge engineer of Iowa origin was Conde B. McCullough, educated at Iowa State College, who worked briefly for J. B. Marsh and then for the highway commission in Ames. He left, however, to become famous for his work in Oregon. Of greater importance for Iowa bridges was Ned Ashton, whose career, however, falls mainly beyond the chronological limits of the HAER recording projects. Ashton did prove his excellence as a structural engineer and bridge designer in the late 1930s and the 1940s with the Grand Avenue Viaduct in Sioux City (HAER No. IA-87), the Centennial Bridge at Davenport (HAER No. IA-73), and the Julien Dubuque bridge at Dubuque. His work, which continued long after the Second World War, still awaits detailed study, as does the work of many of the bridge engineers associated with the Iowa Highway Commission and its successor, the Iowa Department of Transportation.

[63] For further details, see the following, which forms a supplement to this report: James C. Hippen, *Marsh Rainbow Arch Bridges in Iowa* (Boone, Iowa: Boone County, 1997), pp. 5-9 and bibliography, p. 23.

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